Modem Communications Standards

Serial communications standards have made worldwide computer communications possible. Here's a look at the latest standards.

STEPHEN J. BIGELOW

WE HAVE NOW BECOME AN "INFORmation society." Low-cost, high-speed personal computers—now in almost every office, school, and home—allow just about everyone to tap into a variety of national information networks. National information networks such as CompuServe and America Online are now serving millions of users. The Internet, a worldwide network of computer networks, is growing at a rate of about 15% per month. There are now more than 40,000 small, private computer bulletin board systems (BBS) within the U.S.

Personal computers, for the most part, are not equipped to connect directly to the national and global information networks. Instead, they must be connected through the public telephone system. However, because the U.S. telephone system is an analog system, computers require a modem (modulator/demodulator) to translate (or modulate) their digital output into audible sounds that can be sent by telephone lines to a remote location. Those audio signals must then be converted (or demodulated) back into digital information to be "understood" by another computer. This basic concept is illustrated by Fig. 1.

Modems are certainly not new peripherals. They were used with the earliest personal computers. Like PCs themselves, modems have evolved through continuous advances in electronics so that they now can pass ever greater volumes of data over a telephone system whose characteristics have barely changed in 100 years.

A result of this constant improvement is a long list of modem specifications with such names as V.32 and V.42bis. This article will give you a basic understanding of modems, their specifications, and it will help help you to understand some of the confusing jargon associated with the latest modems.

The serial approach

Computers normally process 16- or 32-bit words of digital information on their internal data buses. Even the computer's parallel printer port offers a data path that is 8 bits wide. However, there is only one transmitting wire in a telephone line. Modems must break down each digital word into a sequence of audio signals, and send each signal in turn along the tele-

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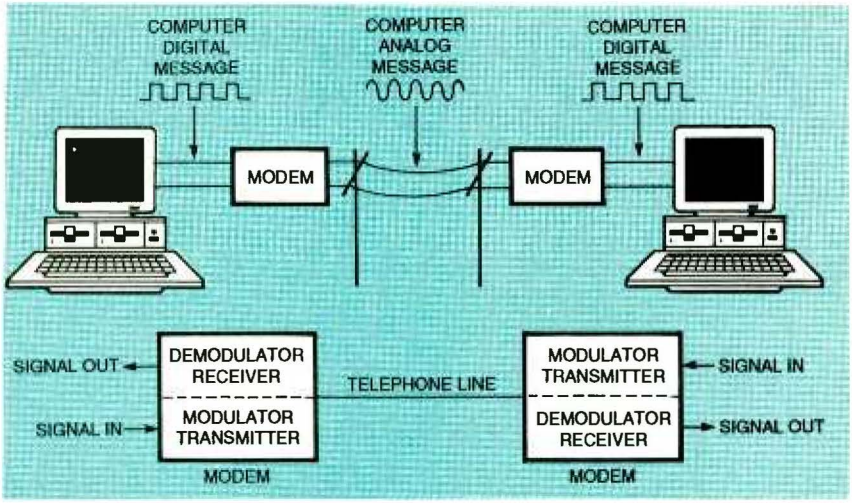

FIG. 1—A MODEM CONVERTS DIGITAL SIGNALS from a computer to analog signals that can be transmitted over telephone lines.

phone wire. An 8-bit data word is sent as eight 1-bit signals.

Most modems for PC communication are *asynchronus* or unsynchronized. (Synchronous modems are more expensive because they require complex circuitry to keep the receiving modem operating in phase with the transmitting modem for the duration of the transmission.) Because two communicating modems are operating asynchronously, the receiving machine must know when a stream of data is being sent, where each stream of data starts and ends, and whether the stream is correct or not. To accomplish this feat, extra bits are added to the data to organize it into a standard sequence known as a *data frame*.

A typical serial data frame consists of four parts as shown in Figure 2: the start bit, the data bits, the parity bit, and the stop bit(s). In its idle state, when no data is being sent, a serial-communications signal normally resides in a logic-1 state. The first logic-0 transition is always interpreted as a start bit. The start bit indicates to the receiving modem when the frame's subsequent bits will arrive. It is essential, however, that both modems be operating at the same transfer speed for the transmitted data to be interpreted correctly.

Data bits follow the start bit. There might be from five to eight data bits in the frame. However, 7- or 8-bit data frames are most common for PC communications. As examples, CompuServe data frames have seven data bits, and most BBS facilities (including the *Electronics Now BBS*) are configured for 8-bit data frames. For successful communications, both modems must be set to expect the same number of data bits.

A parity bit might be added to the frame to aid in error detecting. However, because parity checking is ineffective for detecting more than one incorrect bit in a data word, parity is often deactivated (or set to 'none') through communication software. When activated, parity is either even or odd.

With even parity, the parity bit will be set (made logic 1) if the number of 1's in the data word is even. With odd parity, the parity bit will be set (made logic 1) if the number of 1's in the data word is odd. The receiving modem calculates parity for the data word and compares it with the received parity bit. If a discrepancy occurs, an error is flagged.

One or two stop bits must be added to conclude the data frame. One stop bit is typical for most setups since a second stop bit would be redundant. Stop bits are always logic 1's, which leave the system in the idle state to await the next data frame. Both modems must be set to expect the same number of stop bits.

When you want to connect a computer to a BBS or information service, you must configure your system for the correct data-frame format. The most popular frame format is eight data bits, no parity bit, and one stop bit (commonly written 8,N,1). Another popular format is seven data bits, even parity, and one stop bit (7,E,1).

Port Connections and Signals

The translation from parallel data words to a serial data stream takes place within the computer's serial port circuit in an IC known as a universal asynchronous receiver/transmitter (or UART). Logic 1's and 0's are converted into bipolar signals. Logic 1's are translated to −5 to −15-volt levels (mark), and logic 0's are tralated to +5 to +15-volt levels (space). Those bipolar signals are supplied to the TX (transmit) pin of a standard serial communications port as shown in Fig. 3. Those physical connections are also called RS-232C ports. In Europe, the RS-232C standard is called V.24.

An external modem connected to the serial port modulates the bipolar TX signal into an audio signal which is sent over the telephone line. Audio signals received by the modem and demodulated into bipolar signals are returned to the serial port's RX (receive) pin. An internal modem—that is, a plug-in unit installed inside a

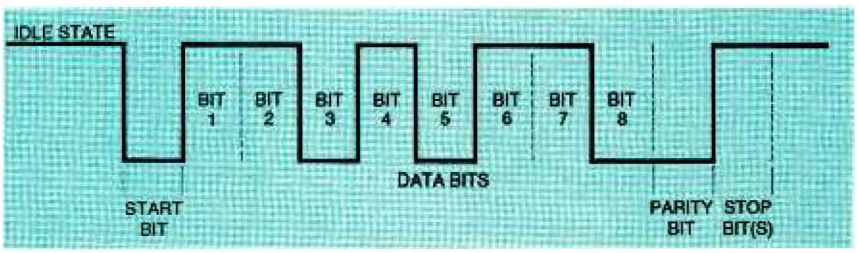

FIGURE 2—A TYPICAL DATA FRAME. This frame is formatted with one start bit, eight data bits, a parity bit, and one stop bit.

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computer—contains a serial port on its circuit board. (You might have to disable a serial port in the computer to prevent hardware conflicts with the internal modem's serial port circuit.) For most serial port connections, only TX, RX, and ground wires are needed to establish a working port.

Communications software

Communications software supplies a "front end" for the control of a modem. It helps to remove some of the complexities associated with modem configuration, modem control codes.

One type of communications software is designed for communications with a specific online service. WinCIM, for example, is the Windows version of the CompuServe Information Manager, which is designed specifically to make it easier to "navigate" the CompuServe information service. Such special-purpose software is outside the scope of this article.

Other communications software is designed for general-purpose communication. Some popular examples include Procomm Plus, Qmodem, and Crosstalk.

All communications software must be able to operate in two distinct modes: the *command mode*, and the *terminal mode*. In the command mode, any commands issued control either the communications software, the host computer, or the modem connected to it. In the terminal mode, any commands issued are sent directly to the modem, or they are sent through the modem and to the remote computer to which it is connected.

Typical instructions that might be issued in the command mode include retrieving a telephone number from a data log, setting the proper communications protocol, dialing a number, and saving any data that is received in a disk file.

In the terminal mode, all keyboard (or disk) input is sent directly to the modem. If the modem is *offline* or not connected to a remote computer, the input is recognized as modem commands. If the modem is *online* and has an active connection to a remote computer, all input is sent through the modem to the remote computer unless certain special control characters precede the data.

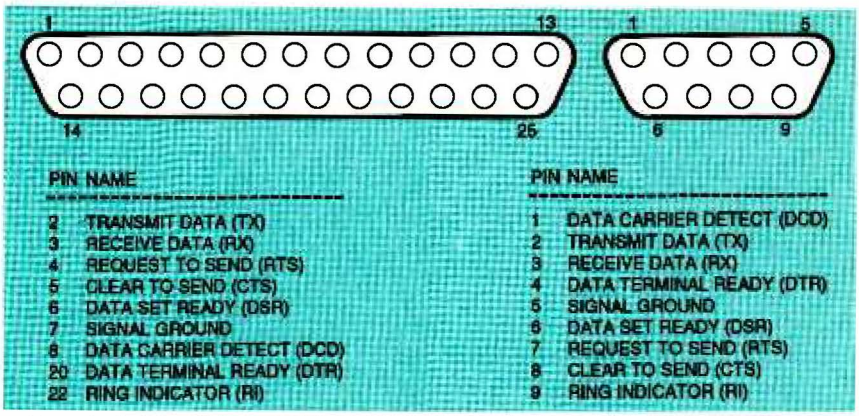

FIGURE 3 - SERIAL PORT CONNECTORS for both 9-pin and 25-pin standards.

The difference between the command mode (in which commands are acted on locally) and terminal mode (in which commands affect the remote computer) is probably the most confusing aspect of modem communications for students and computer beginners.

One common mistake made by newcomers, for example, is to initiate a file transfer in terminal mode without issuing a corresponding command in the command mode. The first command is required to tell the remote computer to send a file. The second is necessary to instruct the host computer to receive it and store it on disk.

Flow control.

To control the flow of data between two modems, software codes (such as XON and XOFF) are passed between them. Communications software interprets such codes and controls modem operation accordingly.

However, the flow of data between a computer and modem is not always controlled by software codes. Instead, additional signal lines in an RS-232 port allow for hardware flow control (or handshaking). The request to send (RTS) line tells a modem to prepare to receive data from the computer. Once the modem is ready to send, it will return a clear to send (CTS) signal to the computer. RTS and CTS signals act together to handle data transfer.

When the computer is ready for operation (but not necessarily ready to send data), it asserts its data terminal ready (DTR) signal. DTR must remain active throughout the entire connection time. The modem sends a data set ready (DSR) signal to the computer after the modem has been activated, and has finished any self-tests or preparation for connection. The DTR and DSR signals establish the connection between modem and computer, but they do not control the flow of data between the two.

If a telephone ring signal is detected at the modem, a ring indicator (RI) signal is sent to the computer. When the modem subsequently picks up the ringing line and detects the presence of carrier, a data carrier detect (DCD) signal is passed to the computer. Ring and carrier detect signals invoke the PC's communication software to receive communication (such as fax messages) from a distant modem.

Modulating the Signals

A modem transmits data by generating a carrier that is then modulated. Several different methods of signal modulation have been developed through the years to improve the efficiency of data transfers. As you might expect, two modems must be capable of the same modulation scheme for successful communications.

Two modems that are commu-

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nicating with each other must generate different carrier frequencies. Each communication standard defines the transmitting and receiving carrier frequency. For example, for 300-baud communication, one modem must have a carrier center frequency of 1170 Hz, and the second must have a center frequency of 2125 Hz. By convention, the modem initiating the call, or the originate-mode modem, has the lower carrier frequency. The modem receiving the call, or the answer-mode modem, has the higher carrier frequency.

In the early days of modem communication, each transition of the audio carrier signal represented a single bit. Each transition is known as a baud, so the baud rate equaled the transmission rate in bits-per-second or bps. Unlike those early modems, modern modem schemes allow two, three, four, or more bits to be encoded into every audio signal transition (or baud). This means that modem throughput now equals two, three, or four times the baud rate being carried on the telephone line.

For example, a modem operating at 2400 baud (2400 audio signal transitions per second) can carry 4800 bps if two bits are encoded onto every baud. The same 2400 baud modem can carry 9600 bps if 4 bits are encoded onto every baud. Today, the modem's baud rate rarely matches the modem's bit rate in bps. If the modem were operating at 4800 baud with 3-bit encoding, it would be transmitting 14,400 bps (14.4 kbps), and so on.

The concept of encoding is different from data compression: Encoding transfers *all* original data bits from one system to another, while data compression replaces repeating sequences of bits with much shorter bit sequences (known as *symbols* or *tokens*). Encoding schemes and data compression are described in more detail later in this article.

Modulation Schemes

All waveforms have three basic characteristics: amplitude, frequency, and phase. Each of those characteristics can be adjusted to represent a bit.

Frequency-shift keying (FSK) is similar to frequency modulation (FM) where only the frequency of a carrier is changed, and it is one of the oldest modulation schemes still in use. FSK sends a logic 1 as one particular

MODEM GLOSSARY

Answer mode—The operating state of a modem that is expecting a call from another computer. (The modem is in its originate mode when calling another computer.) The modem transmits at the defined high frequency of the communications channel, and receives at the defined low frequency.

Asynchronous data transmission—Data transmission between computers in which each data group contains its own start and stop bits to indicate the beginning and end of each character, and there is no control over the time between characters.

AT Command Set—The set of industry-standard commands for the control of a modem. Each command line must start with the two-character attention code AT (or at).

Attention code—A two-character sequence (AT or at) that signals a modem that one or more modem commands are to follow.

Auto answer—A feature that enables a modem to answer the phone automatically after a preset number of rings.

Auto dial—A modem feature that allows it to automatically dial a telephone number.

Auto-reliable mode—A feature that allows two modems to "negotiate" with each other to determine whether they can use error control and data compression during a transmission.

Baud rate—The number of audio transitions transmitted by the modem each second. This usually not the same as the bit rate (or bits-per-second) rate, because a given baud may have more than one bit encoded into it.

Bits-per-second (bps)—The speed at which a modem sends or receives information. For example, a modem that operates at 2400 bits per second can transfer 2400 binary digits each second.

Buffer—In a modem, a storage location in an internal RAM where data is temporarily stored until the modem can process the data.

Carrier—The continuous base signal generated by a modem. The modem modulates this signal (alters its frequency or phase) to encode the data bits to be transmitted.

CCITT—International Telegraph and Telephone Consultative Committee. See ITU.

Clear to Send (CTS)—An RS-232C signal that tells the computer it can start sending information.

Command mode—One of two operating modes for a modem, also called local mode. In its command mode, a modem interprets any information it receives from the local computer as modem commands. It tries to perform the commands sent to it, and it returns result codes indicating the results of the commands.

Communications software—A program that provides an interface for the control of a modem's functions. Examples of communications programs are Smartcom, Procomm, and Crosstalk.

Configuration profile—The present operating characteristics of a modem, stored in the modem's S-registers. Whenever a modem command is issued to change one of the operational characteristics (such as setting the volume control or turning the speaker on or off), the modem changes the values in the S-registers to reflect the changes.

Data Carrier Detect (DCD)—An RS-232C signal that indicates when the modem is receiving a carrier signal from a remote modem.

Data Set Ready (DSR)—An RS-232C signal that tells the computer that the modem is connected to the telephone line.

Data Terminal Ready (DTR)—An RS-232C signal that tells the modem that the local computer is ready for data transmission.

Duplex—See definitions half duplex and full duplex.

Escape sequence—A sequence of three characters (normally +) that switch a modem from the on-line mode to the command mode without breaking the telephone connection.

File transfer protocol—An error-checking protocol for file transfers (such as KERMIT, XMODEM, or YMODEM). The protocol monitors information sent with each block of data. If the received data doesn't match the information used to check the quality of data, the system notifies the sender that an error has occurred and asks for a retransmission.

Flow control—The mechanism that regulates the flow of data between two devices. Modems typically have two methods of flow control: software flow control (XON/XOFF) and hardware flow control (CTS/RTS).

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LAPM (link access procedure for modems)—An error control protocol specified by CCITT V.42. LAPM provides error control when one modem is communicating with another modem that supports LAPM.

Line noise—Random signal disturbances that can occur over telephone lines. Noise can disrupt communications and corrupt the transmitted data.

Loopback test—A diagnostic test in which characters that are sent to the modem are immediately sent back from the modem so the computer can compare the characters sent with the characters received.

MNP (Microcom networking protocol)—Provides error control and data compression when one modem is communicating with another modem that supports MNP. (MNP classes 1 through 4 are specified by CCITT V.42 as a back-up error-control scheme for LAPM.)

Nonvolatile memory (NVRAM)—Solid-state random-access memory that retains the information stored in it even if its power is removed. NVRAM in modems stores configuration information.

On-line mode—One of the two operating modes of the modem, also called data mode. (The other is command mode). In on-line mode, the modem interprets all information sent to it as data, not commands. The only exception is the escape sequence (normally +), which returns the modem to command mode without breaking the connection. The modem is placed in on-line mode when it makes a connection with a remote modem, or when a command is entered to return to a previously established connection.

Originate mode—The state of a modem that is initiating a call to another computer. (The modem is in its answer mode when expecting a call from another computer.) The modem transmits at the defined low frequency of the communications channel, and it receives at the defined high frequency.

Parity—A data-encoding scheme used in computers for checking the validity of transmitted data. This scheme adds an extra bit to each data word, which the transmitting computer selects based on the type of parity the computers agree to use (odd or even). The receiving computer checks each character and flags a parity error if any character has the incorrect number of bits set.

Protocol—A set of rules that governs how data is transmitted. To communicate successfully, two computers must use the same protocol.

Request to Send (RTS)—An RS-232C signal that requests that the modem send data. It initiates all data transmission between the computer (or terminal) and the modem. RTS is answered by a Clear to Send (CTS) signal.

Result codes—The message sent by a modem after it receives a command.

RS-232C—A standardized system for connecting a device to the serial port of a computer or terminal. It is the recommended standard of the Electronic Industries Association (EIA) for exchanging information between data terminal equipment (such as computers) and data communications equipment (such as modems).

S-registers—NVRAM in a modem that stores the current configuration profile (operating characteristics).

Serial port—The circuits and connector that permit a computer to communicate with serial devices such as printers, modems, plotters, and mice. It is also called a COM or communications port.

Start/stop bits—The bits that identify the beginning and end of an data frame in asynchronous data transmission.

Throughput—The total useful information processed or communicated over a specified amount of time. Data compression increases the throughput of a modem by allowing it to send more information in the same number of bits.

Tone dialing—One of two methods for dialing the telephone. With tone dialing, the modem sends standard Touch Tones. Tone dialing is also called dual-tone multi-frequency (DTMF) dialing.

XON/XOFF—A protocol for controlling the flow of data between a modem and its host computer and between two modems (also called software flow control). If the modem receiving data needs time to process the data or perform some other task, it sends an XOFF signal to the sending modem. The sending modem then waits until it receives an XON signal before sending more data. A <CTRL>-S character is usually interpreted as the XOFF command, while XON is usually either a <CTRO>-Q or any character following <CTRL>-S.

frequency (usually 1750 Hz), and a logic 0 is sent as another discrete frequency (often 1080 Hz). Frequencies are typically sent at 300 baud, and each baud can carry one bit, so FSK can send 300 bps. This early technique resulted in the classical "baud equals bps" confusion which still exists today.

Phase-shift keying (PSK) is a close cousin of FSK, but the phase timing of a carrier wave is altered while the carrier's frequency stays the same. A logic 1 or logic 0 is represented by the alteration of the carrier's phase. Because phase can be shifted in several precise increments (for example, 0, 90, 180, and 270 degrees), PSK can encode one, two, three, or more bits bit per baud. A 1200-baud modem using PSK can transmit 2400 bps over an 1800-Hz carrier. PSK in conjunction with FSK can encode even more bits per baud.

In quadrature-amplitude modulation (QAM), both the phase and amplitude of the wave are modulated to encode up to six bits onto every baud, although only four bits are usually reserved for data. Most QAM modems have a 1700-Hz or 1800-Hz carrier and a base rate of 2400 baud, so they can carry up to 9600 bps.

Trellis-coded quadrature-amplitude modulation (TCQAM or TCM) also generates an 1800-Hz carrier at a 2400-baud base rate, but it uses the full 6-bit encoding capability of QAM to provide a rate of 14400 bps. TCM is now the most popular modulation scheme for high-performance modems because data can be checked on-the-fly with high reliability.

Signaling Standards

Most of the present computer communications standards have been developed through international cooperation by the ITU or International Telecommunications Union (formally the CCITT). The ITU sets data communication standards for the world. Its members include the major modem manufacturers, common telecommunication carriers, and government officials.

ITU specifications are characterized by the letter V. The V simply means standard (something like the RS in RS-232). The number following denotes the particular standard. Some standards also add the term "bis" which indicates the second version of a particular standard. You might also see the term "terbo" which is the third

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TABLE 1—ITU STANDARDS

V.1—A very early standard that defines binary digits as space/mark line conditions and voltage levels.

V.2—Limits the audio power levels of modems used on phone lines.

V.4—Describes the data frame.

V.5—Describes the standard synchronous signaling rates for dialup lines.

V.6—Describes the standard synchronous signaling rates for leased lines.

V.7—Provides a list of modem terms in English, Spanish, and French.

V.10—Describes unbalanced high-speed electrical interface characteristics (RS-423)

V.11—Describes balanced high-speed electrical characteristics (RS-422)

V.14—Explains the standard procedure for asynchronous to synchronous conversion.

V.15—Describes the requirements and designs for telephone acoustic couplers. This is rarely used today because most telephone equipment is modular and can be plugged into telephone adapters directly rather than be loosely coupled to the telephone handset.

V.17—Describes an application-specific modulation scheme for Group 3 fax which provides two-wire, half-duplex, trellis-coded transmission at 7200, 9600, 12000, and 14400 bps. Despite its low number, this is a recently introduced standard.

V.19—Describes early DTMF modems for low-speed parallel transmission. This standard is essentially obsolete.

V.21—Provides the specifications for 300 bps FSK serial modems (based on BELL103).

V.22—Provides the specifications for 1200 bps (600 baud) PSK modems (based upon BELL212A).

V.22bis—Describes 2400 bps modems operating at 600 baud with QAM.

V.23—Describes the operation of an unusual FM modem operating at 1200/75 bps. The host transmits at 1200 bps and receives at 75 bps, while the remote modem transmits at 75 bps and receives at 1200 bps. In Europe, V.23 supports some videotext applications.

V.24—This is known as EIA RS-232C in the U.S. V.24 defines only the functions of the serial port circuits. EIA-232E (the current version) also defines electrical characteristics and connectors.

V.25—Defines automatic answering equipment and parallel automatic dialing. It also defines the answer tone that modems send.

V.25bis—Defines serial automatic calling and answering, which is the ITU (CCITT) equivalent of AT commands. This is the current ITU standard for modem control by computers via serial interface. The Hayes AT command set is used primarily in the US.

V.26—Defines a 2400-bps, PSK, full-duplex modem operating at 1200 baud.

V.26bis—Defines a 2400-bps, PSK, half-duplex modem operating at 1200 baud.

V.26terbo—Defines a switchable 2400/1200-bps, PSK, full-duplex modem operating at 1200 baud.

V.27— Defines a 4800-bps, PSK modem operating at 1600 baud.

V.27bis—Defines a more advanced 4800/2400-bps, PSK modem operating at 1600/1200 baud.

V.27terbo—Defines a 4800/2400-bps, PSK modem commonly used in half-duplex mode at 1600/1200 baud to handle Group 3 fax rather than computer modems.

V.28—Defines the electrical characteristics and connections for V.24 (RS-232). Where the RS-232 specification defines all necessary parameters, the ITU breaks the specifications down into two separate documents.

V.29—Defines a 9600/7200/4800-bps, PSK/QAM modem operating at 2400 baud. This type of modem often implements Group 3 fax rather than computer communications.

V.32—Defines the first of the truly modern modems as a 9600/4800-bps, QAM, full-duplex modem operating at 2400 baud. This standard also incorporates trellis coding and echo cancellation to produce a stable, reliable, high-speed modem.

V.32bis—A fairly new standard extending the V.32 specification to define a 4800/7200/9600/12000/14400 bps TCQAM full-duplex modem operating at 2400 baud. Trellis coding, automatic transfer rate negotiation, and echo cancellation make this type of modem one of the most popular and least expensive for general PC communication.

V.32terbo—Continues to extend the V.32 specification by adding advanced techniques to implement a 14400/16800/19200-bps, TCQAM, full-duplex modem operating at 2400 baud. Unlike V.32bis, V.32terbo is not widely popular because of the high cost of compatible components.

V.32fast—The informal name for a standard that the ITU has not yet completed. When finished, a V.32fast modem will probably replace V.32bis with speeds up to 28,800 bps. It is anticipated that this will be the last analog protocol, eventually giving way to all-digital protocols as local telephone systems become entirely digital. It is expected that V.32fast will be renamed V.34 on completion and acceptance.

V.33—Defines a specialized 14400-bps, TCQAM, full-duplex modem operating at 2400 baud.

V.34—The ratified version of V.32fast. It provides for data speeds up to 128 kbps with transmission rates as high as 3429 baud.

V.36—Defines a specialized 48000-bps "group" modem that is rarely used commercially. This type of modem requires several conventional telephone lines.

V.42—Defines a two-stage process of detection and negotiation for LAPM error control.

V.42bis—Extends the V.42 standard to include data compression.

V.50—Sets standard telephony limits for modem transmission quality.

V.51—Outlines required maintenance of international data circuits.

V.52—Describes apparatus for measuring data transmission distortion and error rates.

V.53—Outlines impairment limits for data circuits.

V.54—Describes loop-test devices for modem testing.

V.55—Describes impulse-noise measuring equipment for line testing.

V.56—Outlines the comparative testing of modems.

V.57—Describes the comprehensive test equipment required for high-speed data transmission.

V.100—Describes the interconnection techniques between PDNs (public data networks) and PSTNs (public switched telephone networks).

version of a standard.

The Bell System largely dictated North American telecommunications standards before it was broken up into AT&T and seven regional telephone operating companies in 1984. Before that time, two major standards had been developed that set the stage for future modem development.

BELL103 was the first widely accepted modem standard—simple FSK modulation at 300 baud. This is the *only* standard

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in which the data rate matches the baud rate. It is interesting to note that many modems today still support BELL103 as the lowest common denominator when all other modulation techniques fail.

BELL212A was a second widely accepted modem standard in North America based on PSK modulation at 600 baud to transmit 1200 bps. Many European countries ignored BELL212A in favor of the similar (but not entirely identical) European standard called V.22.

TABLE 2—MODEM STANDARDS COMPARISON CHART

Standard	Data Rate (bps)	Modulation Technique	Baud Rate (baud)	
Bell 103	300	FSK	300	
Bell 212A	1200	PSK	600	
V.17	7200-14400	QAM	7400	
V.21	300	FSK	300	(Bell 103)
V.22bis	2400	QAM	600	(Bell 212A)
V.23	1200/75	FM	2100/1300 & 450/390	
V.26	2400	PSK (full-duplex_	1200	
V.26bis	2400	PSK (half-duplex)	1200	
V.26terbo	2400/120	PSK (full-duplex)	1200	
V.27	4800	PSK	1600	
V.27bis	PSK	1600/1200		
V.27terbo	4800/2400	PSK	1600/120	(Group 3 fax)
V.29	9600/7200/4800	PSK/QAM	2400	(Group 3 fax)
V.32	9600/4800	QAM	2400	
V.32bis	4800-14400	TCQAM	2400	
V.32terbo	14400-19200	TCQAM	2400	
V.32fast	to 28800	TCQAM	to 3429	
V.33	14400	TCQAM	2400	
V.36	48000	Group-line modem		
V.37	72000	Group-line modem		

ITU Standards

After the Bell System breakup, AT&T no longer wielded enough clout to dictate standards in North America—and certainly not to the international community which had developed serious computing interests. At this time, the ITU gained prominence and acceptance in the U.S. All U.S. modems have been built to ITU standards ever since. Table 1 provides a comprehensive description of ITU standards. Although not all of the listed standards relate specifically to modems, all are related to communications. Table 1 will help you to understand the broad specifications that are required to fully characterize the communications environment.

MNP Standards

The Microcom networking protocol (MNP) is a complete hierarchy of standards developed during the mid 1980s. They were designed to work with other modem technologies to provide error correction and data compression. Originally developed by Microcom, Inc., the protocol is now in the public domain.

MNP provides error control and data compression when one modem is communicating with another modem that supports MNP. MNP class 4 is specified by ITU V.42 as a backup error control scheme for LAPM in the event that V.24 cannot be invoked. Out of nine MNP levels, most modern modems support the first five. Each MNP class has all the features of the previous class plus its own.

MNP class 1 (block mode): Data is sent in one direction at a time. It is about 70% as fast as data transmissions with no error correction. This level is now virtually obsolete.

MNP class 2 (stream mode): Data is sent in both directions at the same time. That results in a speed about 84% as fast as data transmissions with no error correction.

MNP class 3: The sending modem strips the start and stop bits from a data block before sending it. The receiving modem then adds start and stop bits before passing the data to the receiving computer. It is about 8% faster than data transmissions with no error correction.

MNP class 4: A protocol (with some data compression) that checks telephone connection quality and uses *adaptive packet assembly*. On a noise-free line, the modem sends larger blocks of data. If the line is noisy, the modem sends smaller blocks of data so that less data must be resent in the event of an error.

MNP class 5: Provides data compression by detecting redundant data and recoding it to fewer bits, thus increasing effective data throughput. A receiving modem decompresses the data before passing it to the receiving computer. MNP5 can speed data transmissions by as much as a factor of two compared with protocols having no data compression or error correction scheme.

MNP class 6: Universal link negotiation allows modems to obtain maximum performance from a line. The modems start at low speeds, then move to higher speeds until the best speed that both modems can work at is found.

MNP class 7: It offers a more powerful data compression process (Huffman encoding) then MNP5. MNP7 modems can increase the data throughput by as much as a factor of three.

MNP class 8: There is no MNP8 at this time.

MNP class 9: It reduces the data overhead encountered with each data packet. MNP9 also improves error correction performance because only the erroneous data must be re-sent instead of re-sending the entire data packet.

MNP class 10: It includes a set of protocols known as *adverse channel enhancements* to help modems overcome poor telephone connections by adjusting data packet size and transmission speed until the most reliable transmission is established.

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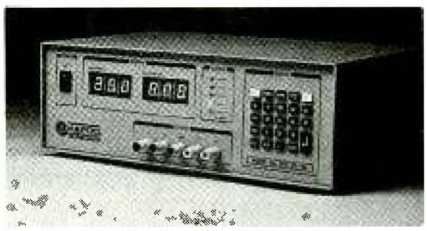

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CIRCLE 190 ON FREE INFORMATION CARD

Data Compression Standards

Most data sent between modems contains some repetitive or redundant information. If the redundant information is replaced by a small "token" during transmission, the data can be compressed.

Data compression has become an important technique that allows modems to increase their data throughput without increasing the baud or bit rate. Data compression can occur only when the two communicating modems support the same compression protocol.

MNP class 5: This standard includes data-compression algorithms that provide up to 2:1 data compression. In effect, MNP5 can give a 2400-bps modem an effective data throughput of as much as 4800 bps; it can give 9600-bps system as much as 19,200 bps.

MNP class 7: Huffman encoding provides a data-compression ratio of up to 3:1. Although it is more efficient than MNP5, not all modems are compatible with it. MNP7 is still generally slower than the ITU's V.42bis.

V.42bis: This standad is a Lempel-Ziv-based data compression scheme for use in conjunction with V.42 LAPM (error correction). V.42bis can compress data by as much as 4:1 (depending on the file sent). Thus, a 9600-baud modem can transmit data at up to 38,400 bps using V.42bis. A 14.4 kbps modem can transmit up to a startling 57,600 bps.

Error Control/Correction Standards

Modem error correction is the ability of some modems to detect data errors that might have occurred in transit between modems, then automatically resend the faulty data until a correct copy is received. As with modulation standards, both modems must be using the same error correction standard to operate together. However, there are few error correction standards, and most modem manufacturers adhere closely to the few that are available.

MNP class 4 is a Microcom error correction protocol (with some data compression) that checks the quality of the telephone connection and adjusts information in the headers of data blocks using a technique called *adaptive packet·assembly*. If the telephone line is relatively noise-free, the modem sends larger blocks of data to increase throughput. If the telephone line is noisy, the modem sends smaller blocks of data so that less data will have to be resent. This means more successful transmissions on the first try. Because it is about 20% faster than data transmissions using no error correction at all, most modems are now MNP4 compatible.

V.42 is the only ITU error correcting procedure for modems that includes the V.22, V.22bis, V.26ter, V.32, and V.32bis protocols. The standard is also defined as the link access procedure for modems (LAPM) protocol. ITU V.42 is considered very efficient, and is about 20% faster than MNP4. If a V.42 connection can't be established between modems, V.42 automatically provides fallback to MNP4 error correction.

Fax modems

A fax modem is a modem that is capable of sending and receiving faxes as well as data. Virtually all fax modems are compatible with the ITU Group 3 standard. The basic operating principles are similar for modems and fax modems. The data that is transmitted, however, represents picture elements or *pels* instead of pure data.

Communications software that is designed to work with fax modems makes it possible to fax documents created in a word processor without the interim step of printing. Faxes that are received can be converted into a text file (rather than graphic image) with character-recognition software.

Computer communication has come a long way in the last decade. From their humble beginnings of 300 bps, today's modems can effectively and reliably pass the equivalent of 57,600 bps using error correction and data compression. Ω

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